Appendix E

Cost-Effectiveness Analysis Model

Cost-Effectiveness Analysis Model

As discussed in the report, certain factors need to exist for cold-ironing to be cost effective: a number of ships have to make several annual visits to the same terminal, the berthing times need to be of sufficient duration, and the ships have to require a significant power demand. Staff developed a spreadsheet to evaluate these and other important variables in determining the cost effectiveness of cold-ironing ocean-going vessels. Table E-1 contains an example spreadsheet that includes inputs for evaluating cold-ironing three reefer ships that visit the same berth. The example illustrates the case where the ships are modified to carry a transformer at $1.5 million per ship. Shore-side cost was estimated at $3.5 million. The major input values are in bold print, including:

- Ship-side cost
- Shore-side cost
- Berthing time
- Annual ship visits
- Number of ships visiting same berth
- Total auxiliary engine power, in kW
- Percent load for engines
- Cost of electricity from grid
- Auxiliary engine operating cost

Table E-2 provides values for some of the ship characteristics used in the cost-effectiveness analysis, by ship category, including: 1) total capacity of auxiliary engines (both an average value used for emissions inventory purposes and the range of total capacity used in the cost-effectiveness analysis); 2) average load; 3) berthing time (both an average value used for emissions inventory purposes and the range of berthing times used in the cost-effectiveness analysis); 4) annual visits (both an average value used for emissions inventory purposes and the range of visits used in the cost-effectiveness analysis); and 5) the range of electrical cost.

In addition, information on the derivation of the cost for operating an auxiliary engine on distillate fuel is included in Attachment E-1.

Because of the complexity of the container-ship category, additional information was included in the following appendix, Appendix F, on the cost-effectiveness analysis for this category. The appendix provides additional examples for how the total capacity of auxiliary engines was established, and how the berthing times and annual visits were established.

Table E-1: Example spreadsheet used to calculate cost-effectiveness values for cold-ironing three reefer ships

CAPITAL COSTS		**SHIP OPERATING DATA**			
		berthing time			
Ship side		**(hours/visit)**	**60**		
ship retrofit costs ($ per ship)	**$1,500,000**	hookup time	2		
total capital costs	$4,500,000	net time	58		
annual costs-10	$582,750	**annual visits**	**17**		
Shore side		**REPEATING COST**			
shore cost ($ per terminal)	**3,500,000**	**Labor costs**			
affected berths	1	electrician costs	100	$/hr	
total capital costs	$3,500,000	hours	8		
annual costs-10	$453,250	annual occurances	102		
		staff required	3		
A/P factor-10 year	0.1295	costs	$244,800.00		
Summary of Cost		**Electrical costs**			
ship annual capital recovery costs	$582,750	grid cost	**16**	cents/kw	
shore annual capital recovery costs	$453,250	aux eng op cost	**11**	cents/kw	
repeating cost	$547,403				
total	$1,583,403	cost per visit per ship	$5,933.40		
		total costs	$302,603.40		
		total kW	6,260,760.00		

	Number of frequent flyer ships	Total auxiliary engine power (kw)	% load	NOX (TPY)	PM (TPY)	ROG (TPY)	SOX (TPY)
ship emissions	**3**	**3300**	**0.62**	92.6	1.7	2.7	1.7
power plant emissions				0.6	0.1	0.1	0.0
net emissions				92.0	1.6	2.6	1.6

Emission Factors for Calculation

NOx EF	13.9	g/kw-hr
PM EF	0.25	
ROG	0.4	
SOX	0.25	

Fuel Specific Emission Factors

	mgo (0.5%S)	mgo (0.1%S)
NOx EF	13.9	13.9
PM EF	0.38	0.25
ROG	0.4	0.4
SOX	2.1	0.25

RESULTS

Percentage costs		**Cost Effectiveness cost in 2005 dollars**	**$1,583,403**
ship	**36.8**		
shore	**28.6**		
labor	**15.5**	**$/ton nox**	**$17,207**
electricity	**19.1**	**$/ton pm**	**$1,004,993**
		$/ton all pollutants	**$16,194**

Table E-2: Ship Characteristics Used in Cost-Effective Analysis

Category	Average Total Auxiliary Engine Capacity	Range of Total Auxiliary Engine Capacity	Load (percent of full load)	Berthing Time	Annual Visits	Electrical Cost
Container ship	6,500 kW	5,800 to 7,500 kW	0.19	65 hr/visit average with range of 4-230 hr/visit for POLA/POLB; 22 hr/visit average with range of 8-65 hr/visit for Oakland	Average of 8 visits per year with range of 1 to 25 visits per year for POLA/POLB; Average of 6 visits per year with range of 1 to 23 visits per year for Oakland	8-10 cents per kw
Passenger	NA	6 to 11 MW*	NA	10 hr/visit	Average of 21 visits per year with range of 1 to 105 visits per year	18-69 cents per kw
Reefer	3900 kW	3,300 to 4,200 kW	0.3-0.6	60 hr/visit	Average of 12 visits per year with range of 1 to 17 visits per year	11-22 cents per kw
Tanker—diesel-electric crude	NA—5 MW for pumping; 800 kW hotelling*	NA	NA	37 hr/visit; 24 hr/visit for pumping	range of 6 to 22 visits per year	18-47 cents per kw

Tanker—non-diesel-electric crude	NA—600 kW for hotelling*	NA	NA	Average of 37 hr/visit with range of 11 to 130 hr/visit for POLB; Average of 20 hr/visit with range of 9 to 25 hr/visit for Bay Area ports	Average of 9 visits per year with range of 1 to 47 visits per year	9-13 cents per kw
Tanker--product	NA—1.5 MW for pumping; 500 kW hotelling*	NA	NA	25 hr/visit; 19 hr/visit for pumping; pumping occurs 60% of visits	Average of 4 visits per year with range of 1 to 47 visits per year	9-110 cents per kw
Vehicle carrier	2,850 kW	NA	0.26	45 hrs/visit	Average of 8 visits per year with range of 1 to 9 visits per year	8-59 cents per kw
Bulk	1,000 kW *	NA	NA	20 hr/visit for Oakland; 77 hr/visit for all other ports	Average of 2 visits per year with range of 1 to 19 visits per year	8-14 cents per kw

* actual power consumption

Attachment E-1

Auxiliary Engine Fuel Costs

Assumptions/Basis

- Fuel costs: $485/metric ton for MGO

  Estimate taken from Lloyd's List, Bunker 60—Web page: http://www.lloydslistbunker60.com/

- Diesel engine efficiency: 35 percent
- Energy Content: 135,000 BTU/gal for MGO
- Density fuel: 306 gal/metric ton for MGO

Cost for using MGO

3413 BTU/kW x $485/metric ton x metric ton/306 gal x gal/135,000 BTU / 35 percent

= $0.11 per kW-hr

Summary

Cost effectiveness calculations will use $0.11 per kW-hr for MGO